Most of the loops mentioned above have confidence counters associated with them to insure proper operation. However, the build-up or let-down of confidence is not designed to be equal. The confidence counters buildup confidence quickly for quick acquisition times, but lose confidence slowly to maintain operation in noisy environments. The VSB receiver will work in S/N conditions of 0 dB or less as well as in severe interference situations.

6.3.0 High Speed Cable Mode System Description

The high data rate cable mode trades off transmission robustness (28.3 dB signal-to-noise threshold) for system data rate (43 Mbit/sec). Most parts of the cable mode VSB system are identical or similar to the terrestrial system. A pilot, data segment sync, and data field sync are all used to provide robust operation. The pilot in the cable mode also adds 0.3 dB to the data power. The symbol, segment, and field signals and rates are all the same, allowing either receiver to lock up on the other's transmitted signal. Also, the data frame definitions are identical. The primary difference is the number of transmitted levels (8 versus 16) and the use of trellis coding and NTSC interference rejection filtering in the terrestrial system.

The RF spectrum of the cable modem transmitter looks identical to the terrestrial system, as illustrated in Fig 21. Peak-to-average power ratio, shown in Fig 22, is very similar between the two VSB systems. The 16-VSB has slightly higher peak-to-average power ratio due to its 16- level random data. The error probability of 16-VSB, shown in Fig 23, is about 28.3 dB ($3x10^{-6}$), with forward error correction provided by Reed-Solomon. Fig 24 illustrates a typical data segment, where the number of data levels is seen to be 16 due to the doubled data rate.

Fig 25 shows the block diagram of the transmitter. It is identical to the terrestrial VSB system except the trellis coding is replaced with a Mapper which converts data to multi-level symbols. This conversion is performed by the trellis coding in the terrestrial VSB system. The receiver, shown in Fig 26, is identical to the VSB terrestrial receiver, except that the trellis decoder is replaced by a slicer, which translates the multi-level symbols into data. Also note that no NTSC interference rejection filter is required in the cable mode since strong cochannel signals are not present on cable. The lack of trellis coding and NTSC cochannel interference rejection results in a cost savings in the cable modem.

6.4.0 Summary

The VSB transmission system provides high performance and low cost in both the terrestrial and cable modes. The terrestrial mode combines R-S and trellis coding with an NTSC rejection filter for maximum coverage area during and after the ATV transition period. Both the terrestrial and cable modes make use of a pilot, segment sync, and training signal for virtually no implementation loss. This means that theoretical performance is possible today without relying on future improvements. This performance is also achieved with minimal hardware complexity.

Factors contributing to low cost receivers are:

Simple Carrier Recovery (FPLL) using small pilot
Standard technology IF SAW filters
High immunity to phase noise (phase tracker) for inexpensive tuners
Symbol-spaced sampling for all data processing circuits
Single A/D converter (I channel only)
Simple Clock Recovery using data segment syncs
Real T-sampled Adaptive Equalizer operating at 10.76 MHz

6.5.0 Future Considerations

During the first round of ATV testing, the 4-VSB system demonstrated a bi-rate capability whereby some data was transmitted more robustly in exchange for a lower net data rate. As delivered for G-A testing, the VSB systems will be configured to provide all the data at equal robustness. Bi-rate data can be a future option if considered important by the Advisory Committee. Bi-rate transmission in the trellis-coded VSB transmission system will have the same data and robustness tradeoffs as in the 4-VSB system already evaluated by the advisory committee.

The cable mode has the capability of being flexible in that the data rate can be traded for a lower white noise threshold, all under headend control. A given 6 MHz RF channel on the cable can be set to have a lower data rate by sending fewer bits/symbol, thus gaining white noise performance. The receiver knows what multi-level data is being transmitted by reading a binary code (always transmitted 2-level during the data field sync). This provides a cable operator with system flexibility as channels are added to the cable system.

6.6.0 References

[1] Zenith [September 1991] Digital Spectrum Compatible HDTV: Technical Details. Monograph published by Zenith Electronics Corp & AT&T Bell Laboratories. FCC ACATS Document SS/WP1-0193.

[2] AT&T and Zenith Electronics Corporation, Oct. 26, 1992, DSC-HDTV System Improvements, submitted to Technical Sub-Group of the ATV Special Panel on Proposed ATV System Improvements.

[3] Certification Presentation, Systems Subcommittee, Working Party 1, Washington, D.C., November 6, 1991.

[4] VSB Transmission System Technical Details, Dec. 17, 1993, by Zenith Electronics Corp., submitted to Transmission Expert Group of the Technical Sub-Group of the ATV Special Panel.

TABLE 6.1 - VSB Parameters

Parameter	Terrestrial Mode	High Data Rate Cable Mode
Channel Bandwidth	6 MHz	6 MHz
Excess Bandwidth	11.5%	11.5%
Symbol Rate	10.76 MSPS	10.76 MSPS
Bits per Symbol	3	4
Trellis FEC	2/3 rate	None
Reed-Solomon FEC	T=10 (208,188)	T=10 (208,188)
Segment Length	836 Symbols	836 Symbols
Segment Sync	4 symbols per segment	4 symbols per segment
Frame Sync	1 per 313 segments	1 per 313 segments
Payload Data Rate	19.3 Mb/s	38.6 Mb/s
NTSC Co-Channel Rejection	NTSC Rejection Filter in receiver	N/A
Pilot Power Contribution	0.3 dB	0.3 dB
C/N Threshold	14.9 dB	28.3 dB

Figure 1
VSB Data Frame

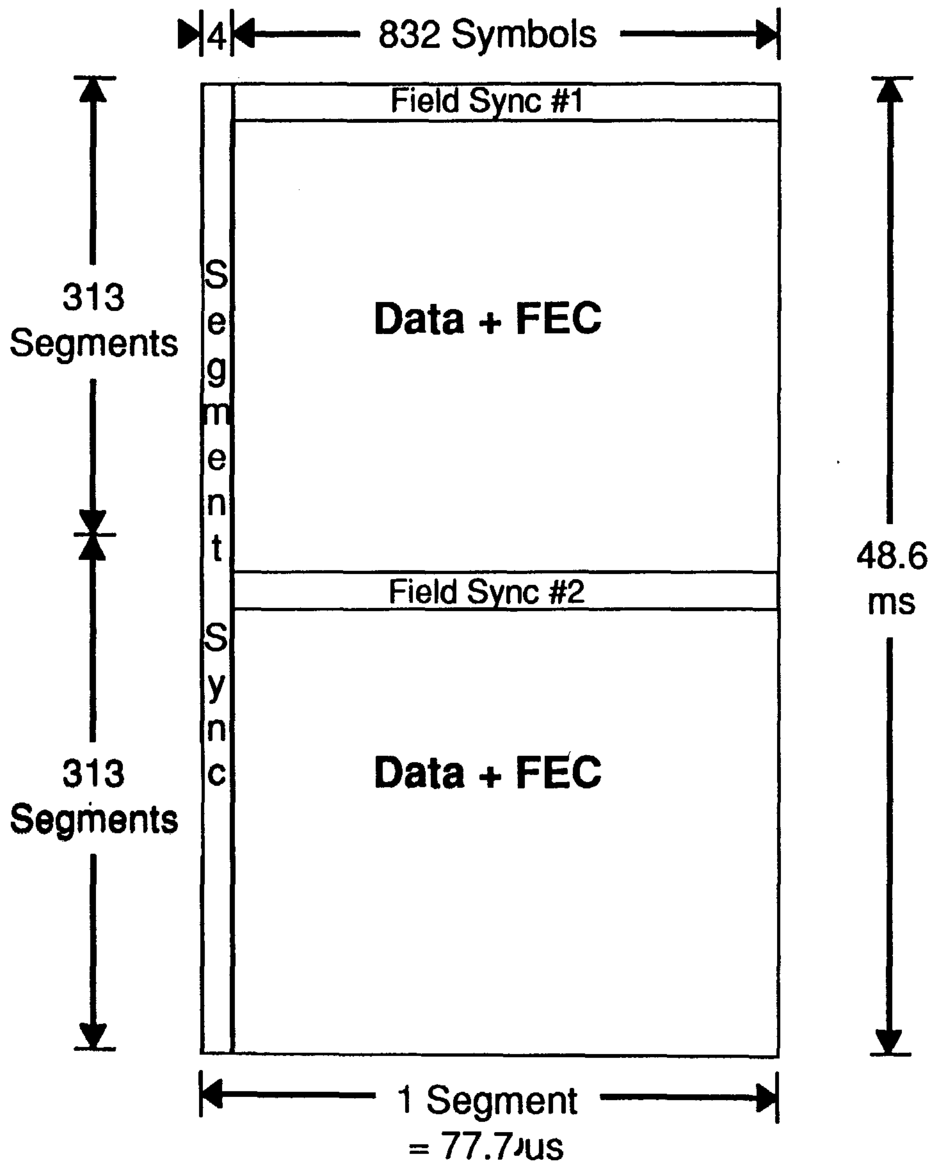


Figure 2

VSB AND NTSC CHANNEL OCCUPANCY

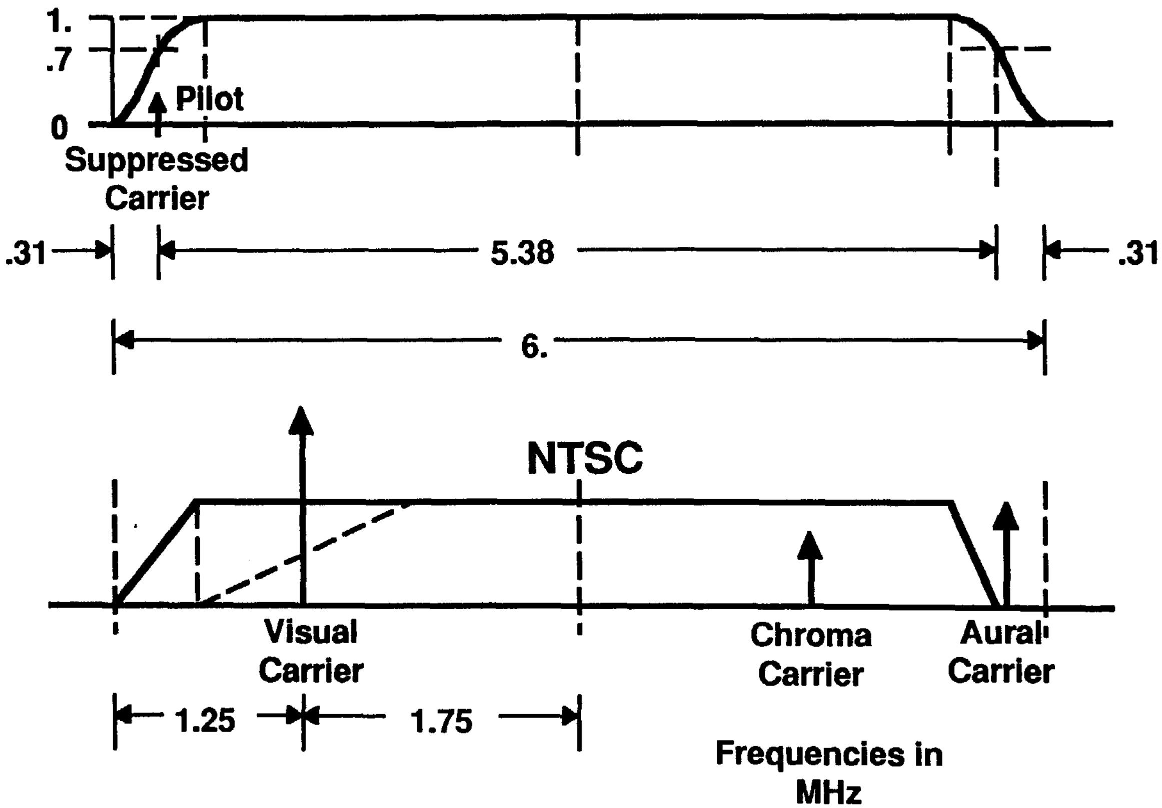


Figure 3

CUMULATIVE DISTRIBUTION FUNCTION OF 8-VSB PEAK-TO-AVERAGE POWER RATIO

Figure 4

SEGMENT ERROR PROBABILITY
8vsb w/4state trellis; RS=(208,188)

Figure 5

VSB TRANSMITTER

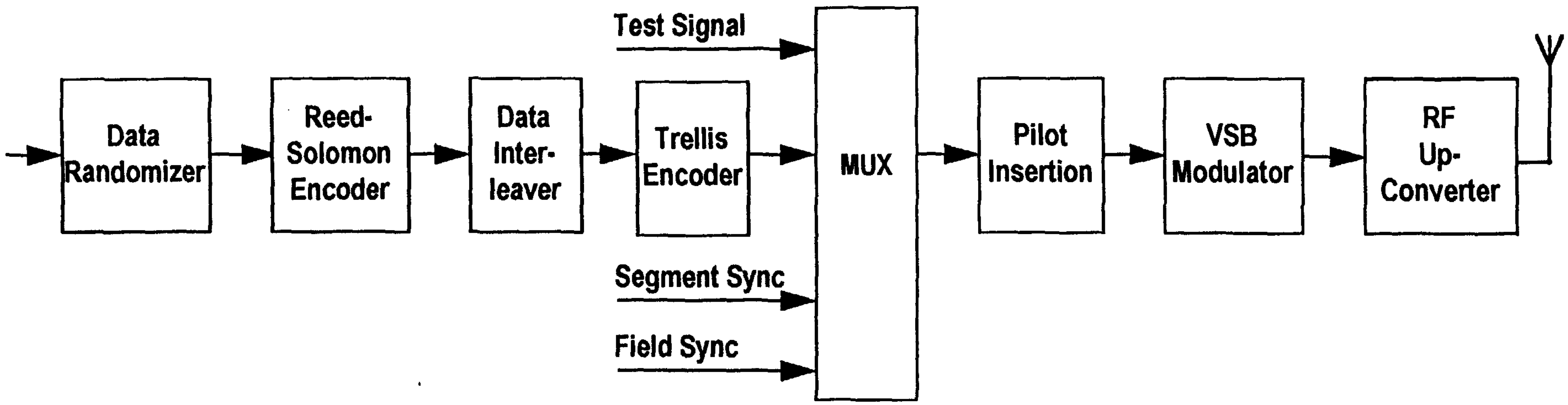


Figure 6

VSB DATA SEGMENT (Terrestrial)

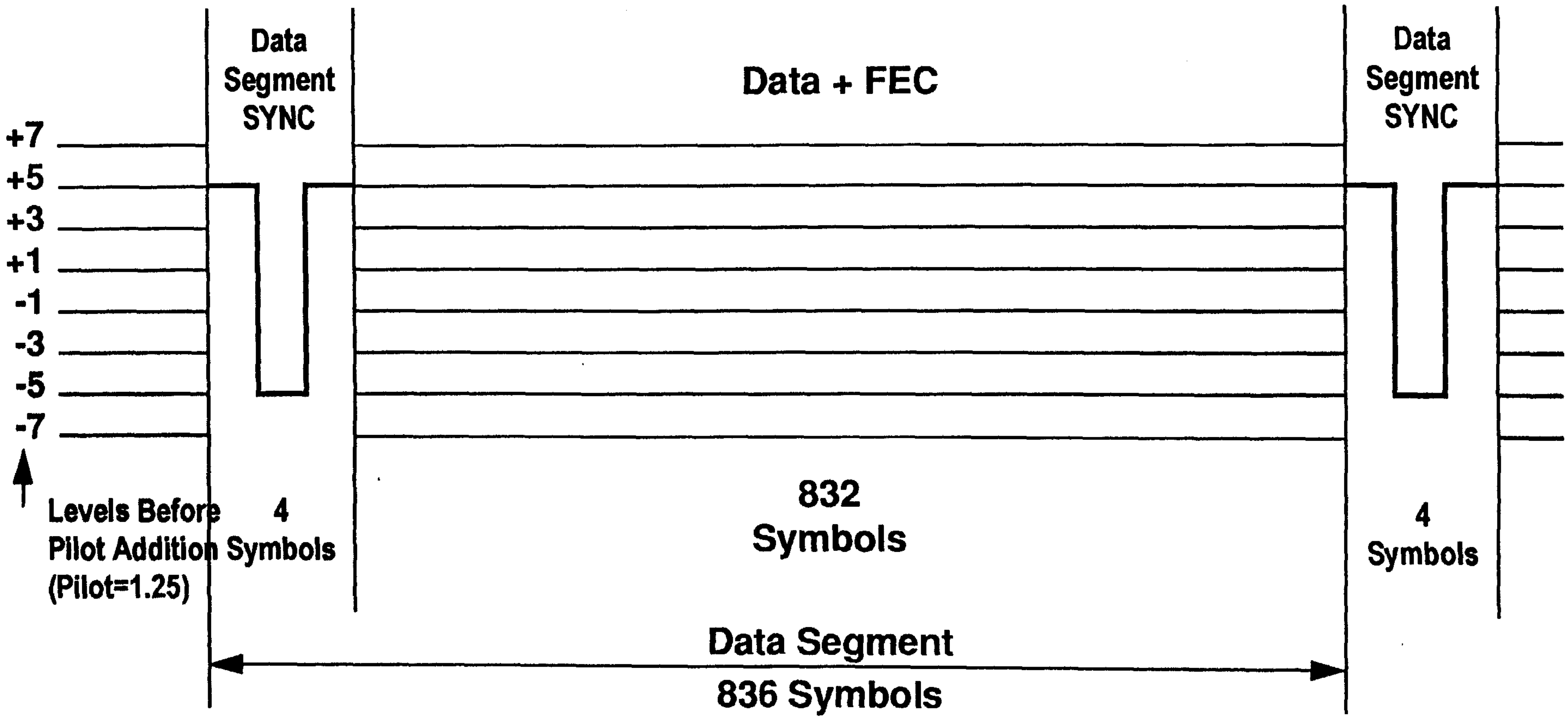
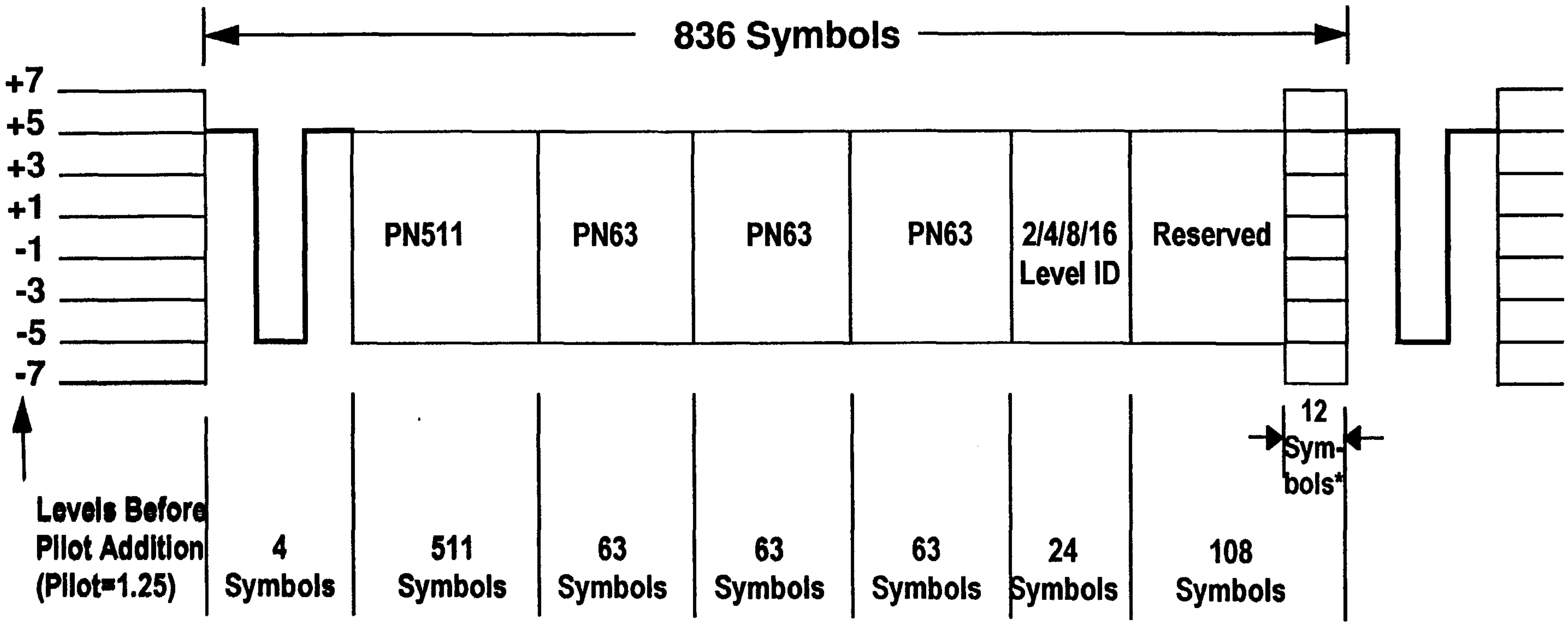


Figure 7

VSB DATA FIELD SYNC



* For 8-VSB the last 12 symbols of the previous segment are duplicated in the last 12 reserved symbols of the field sync.

Figure 8

NOMINAL VSB SYSTEM CHANNEL RESPONSE
(Linear Phase Raised Cosine Nyquist Filter)

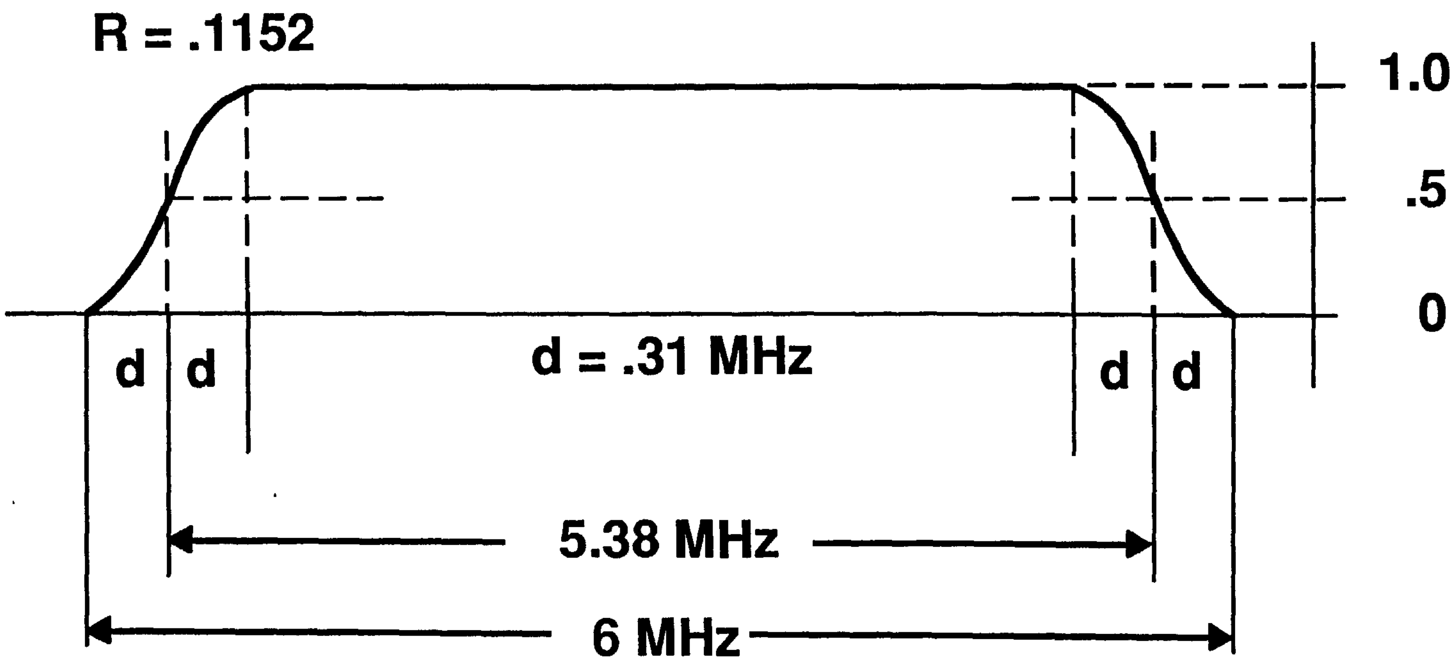


Figure 9

VSB RECEIVER

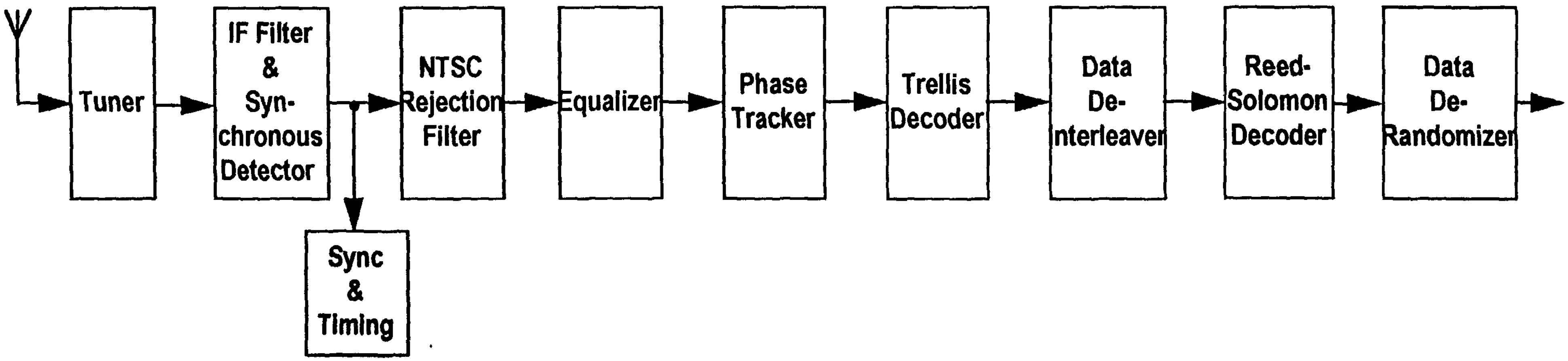


Figure 10

TUNER BLOCK DIAGRAM

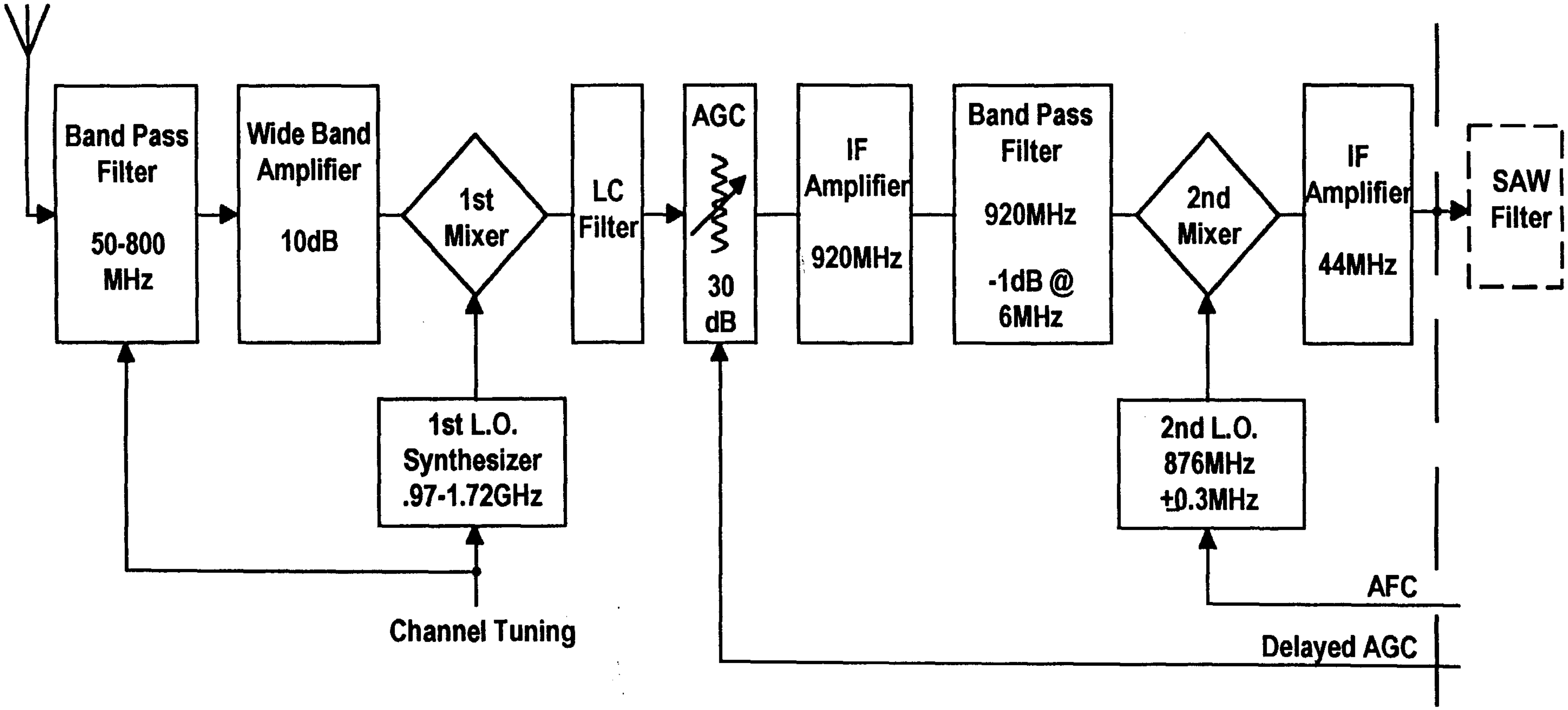


Figure 11

TUNER - IF - FPLL

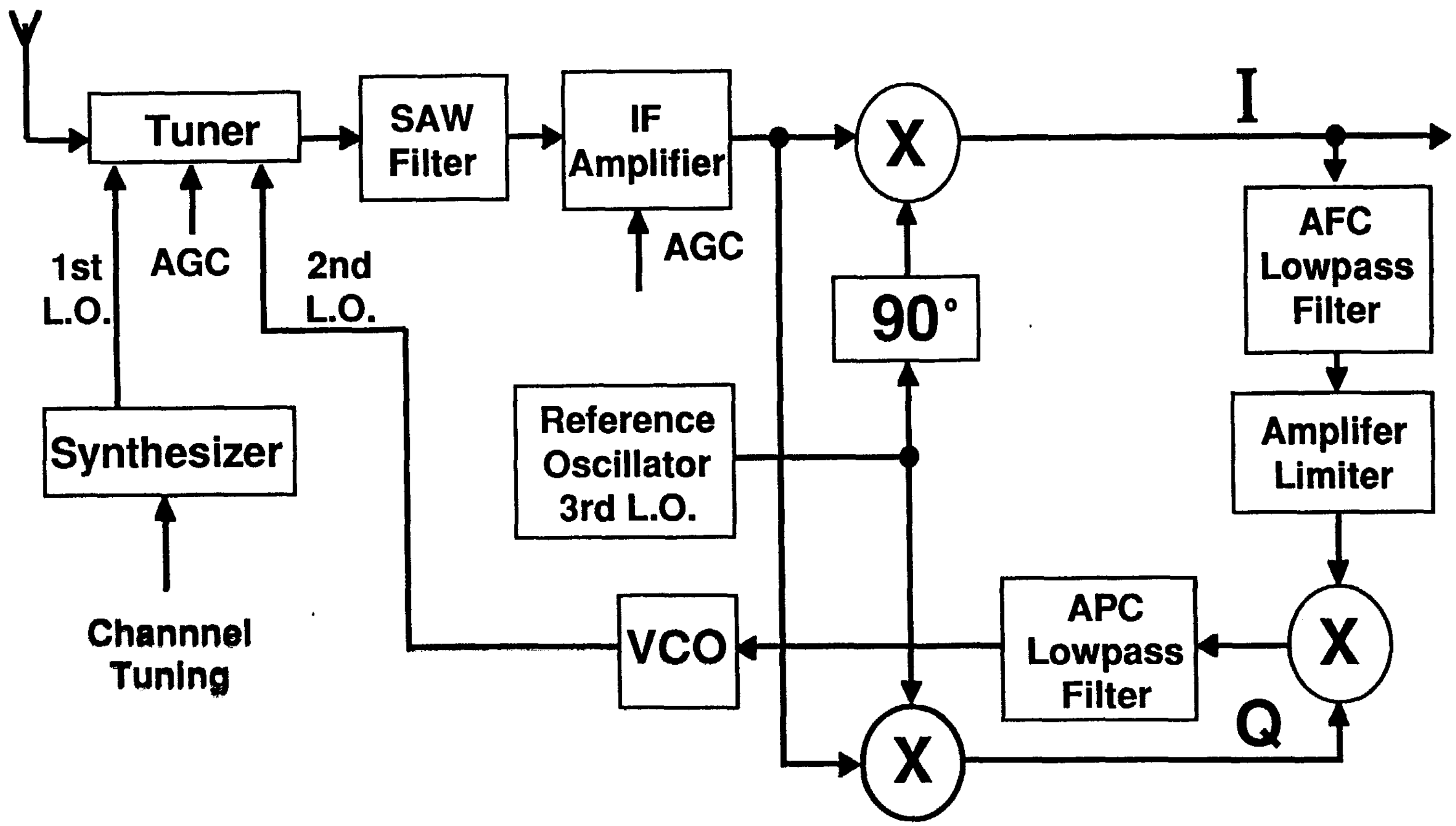


Figure 14

DATA FIELD SYNC RECOVERY

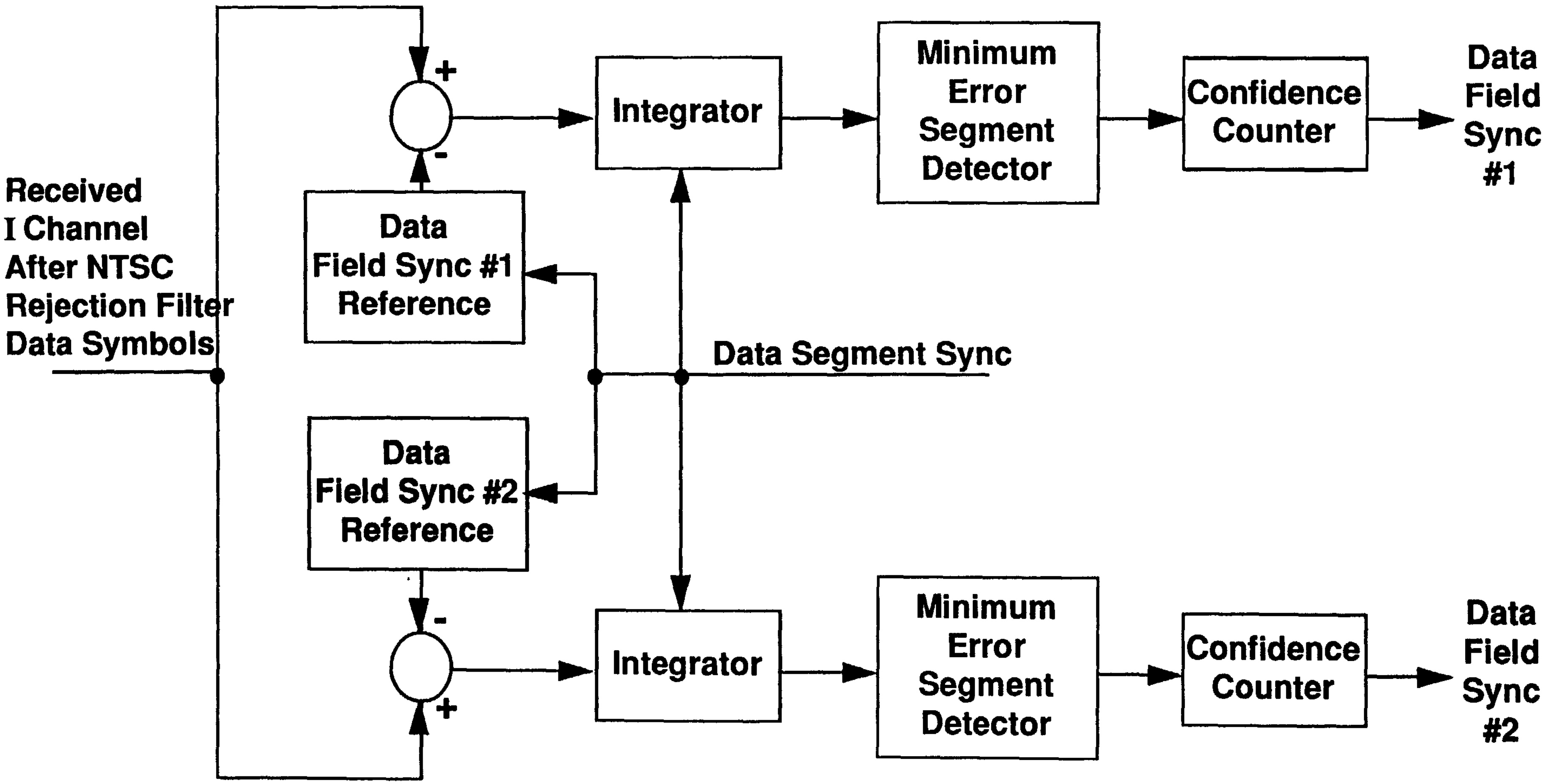


Figure 16
NTSC INTERFERENCE DETECTION

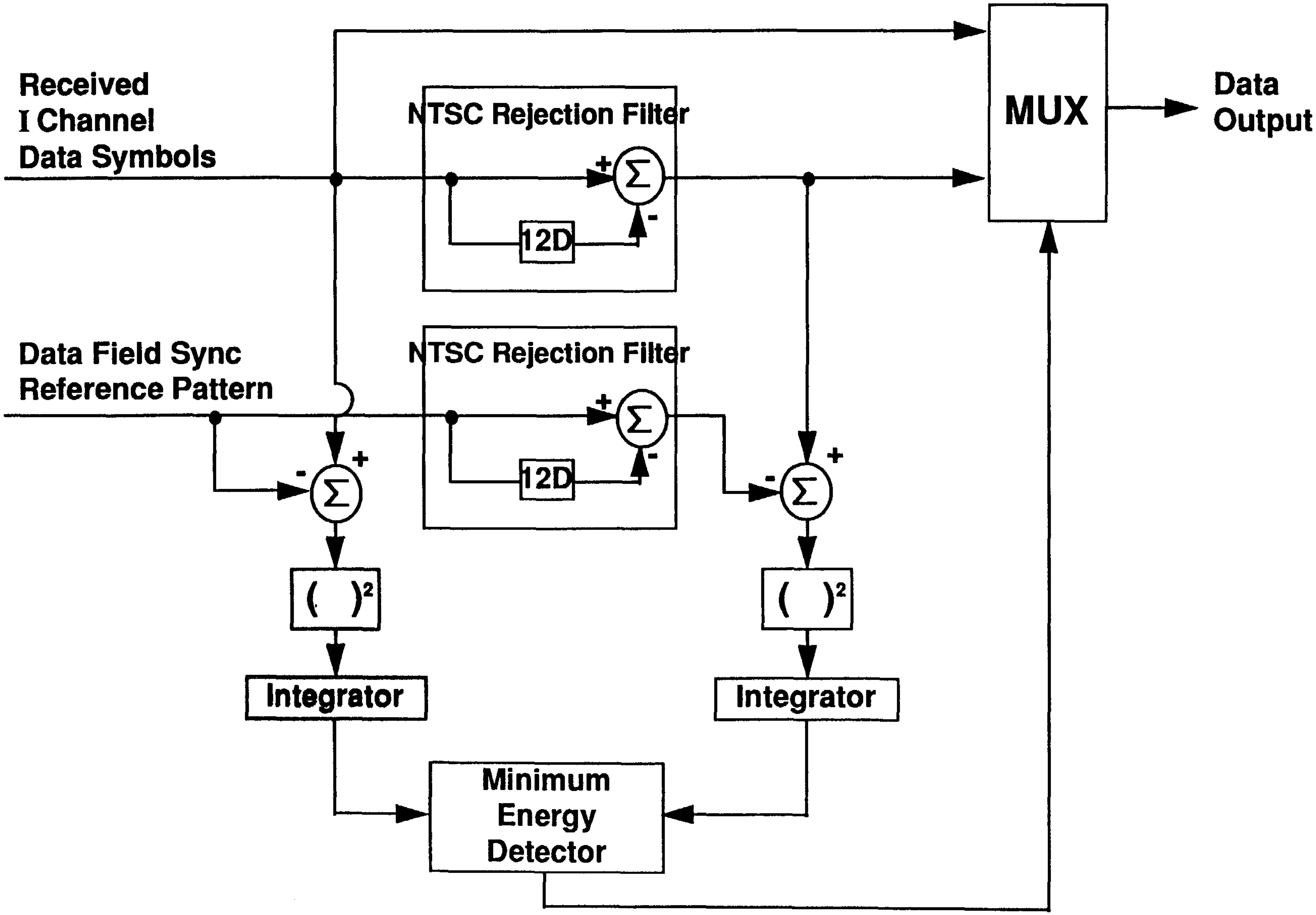


Figure 17
VSB EQUALIZER SYSTEM

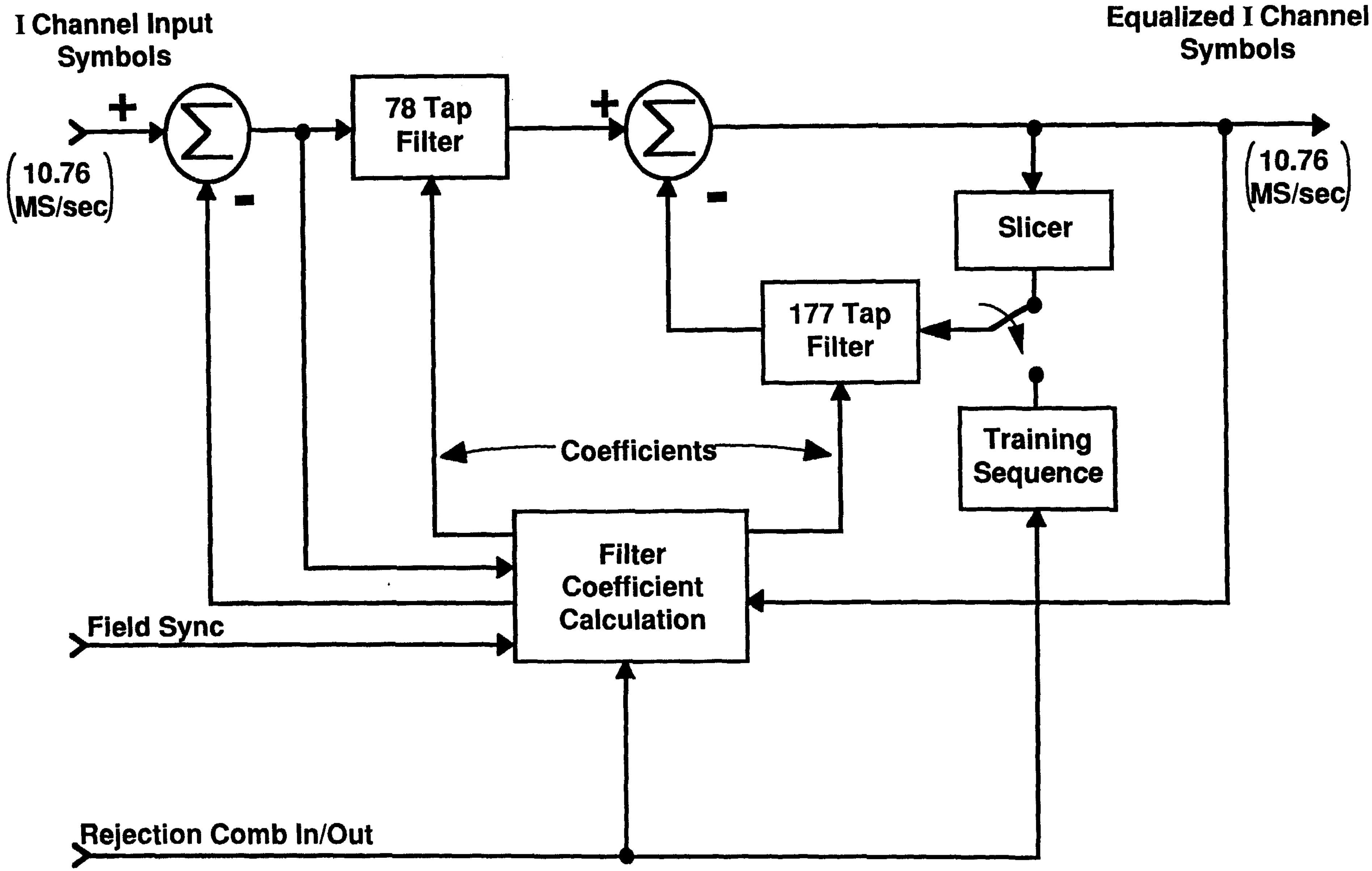


Figure 18

PHASE TRACKING LOOP

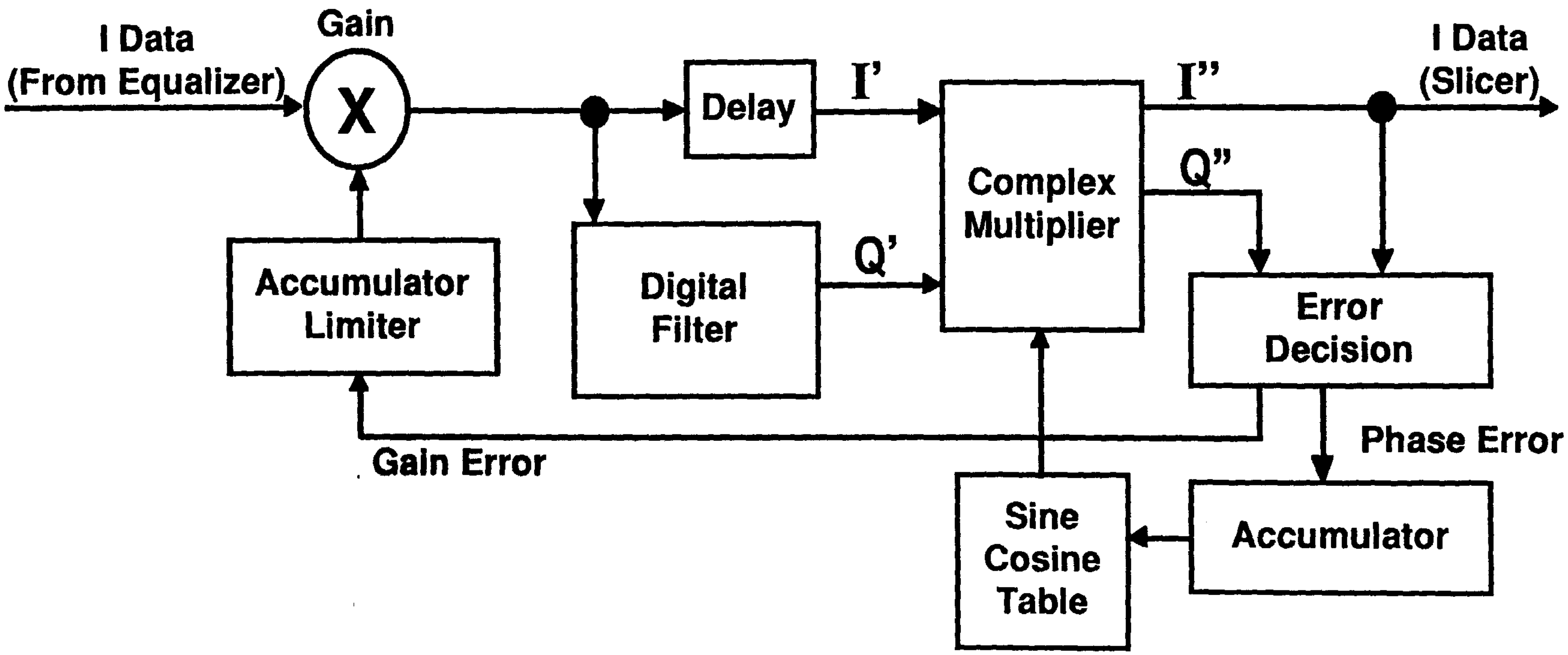


Figure 19
TRELLIS CODE DE-INTERLEAVER

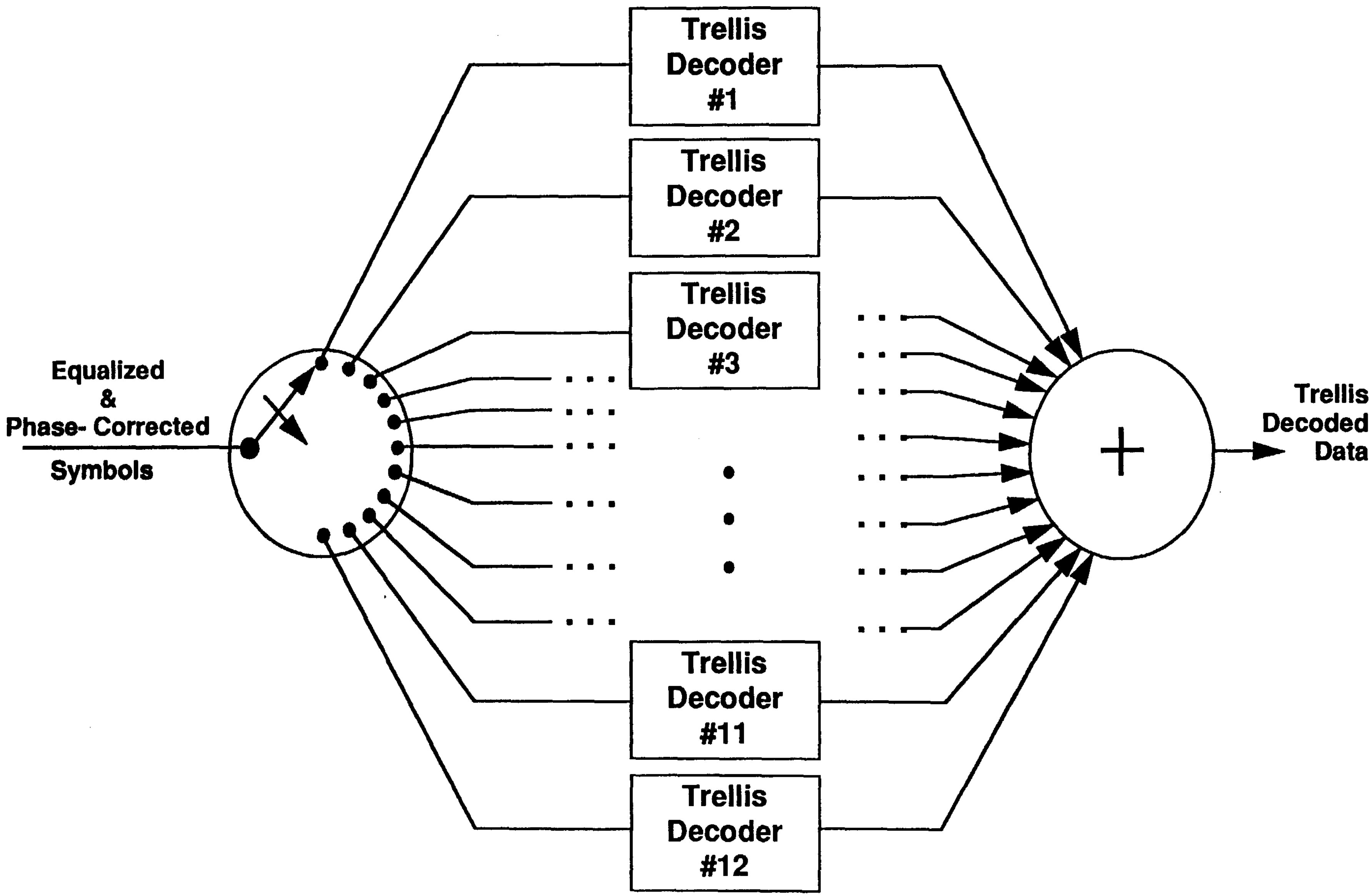


Figure 20

TRELLIS DECODING WITH AND WITHOUT NTSC REJECTION FILTER

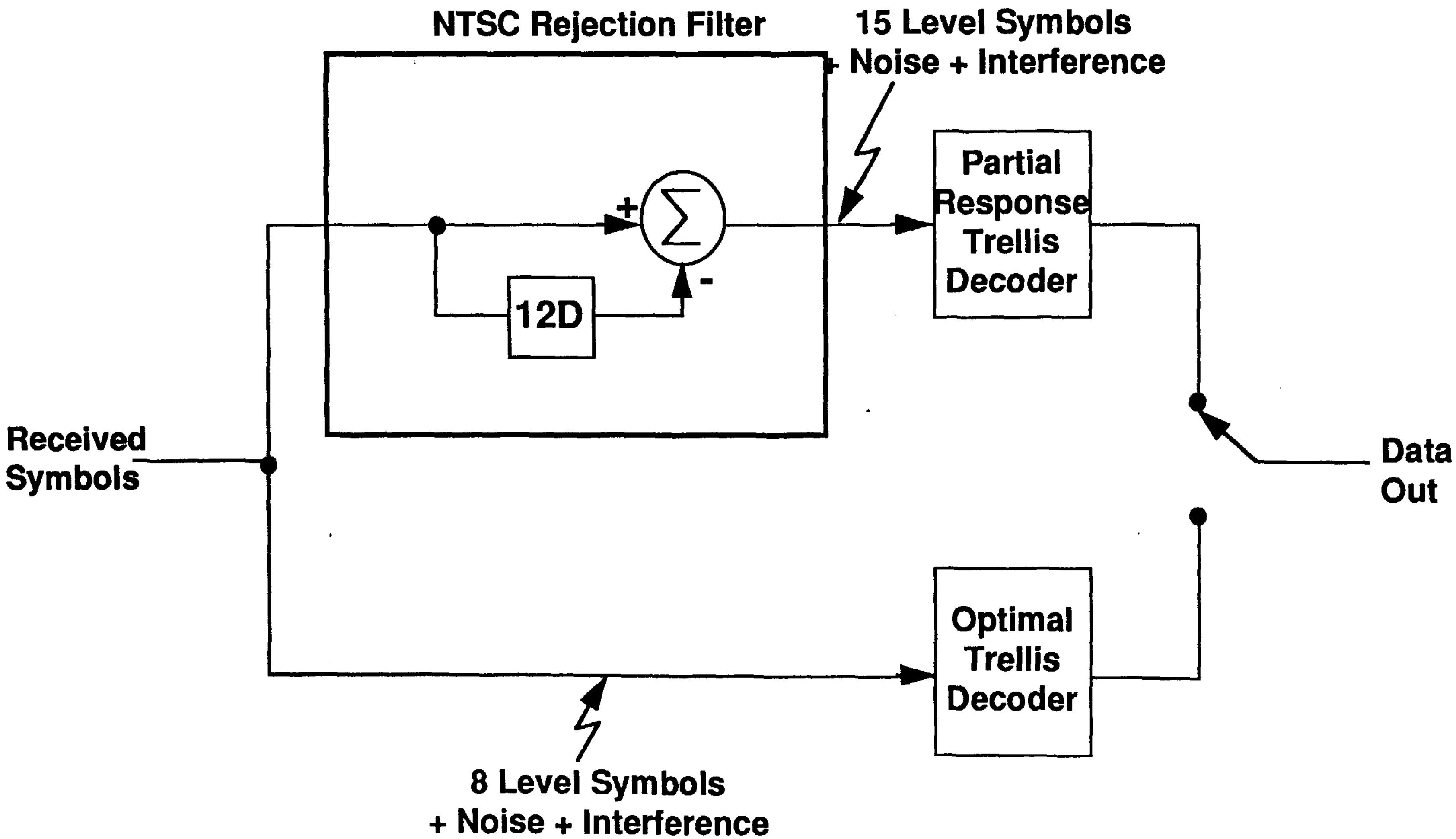


Figure 21

16-VSB AND NTSC CHANNEL OCCUPANCY

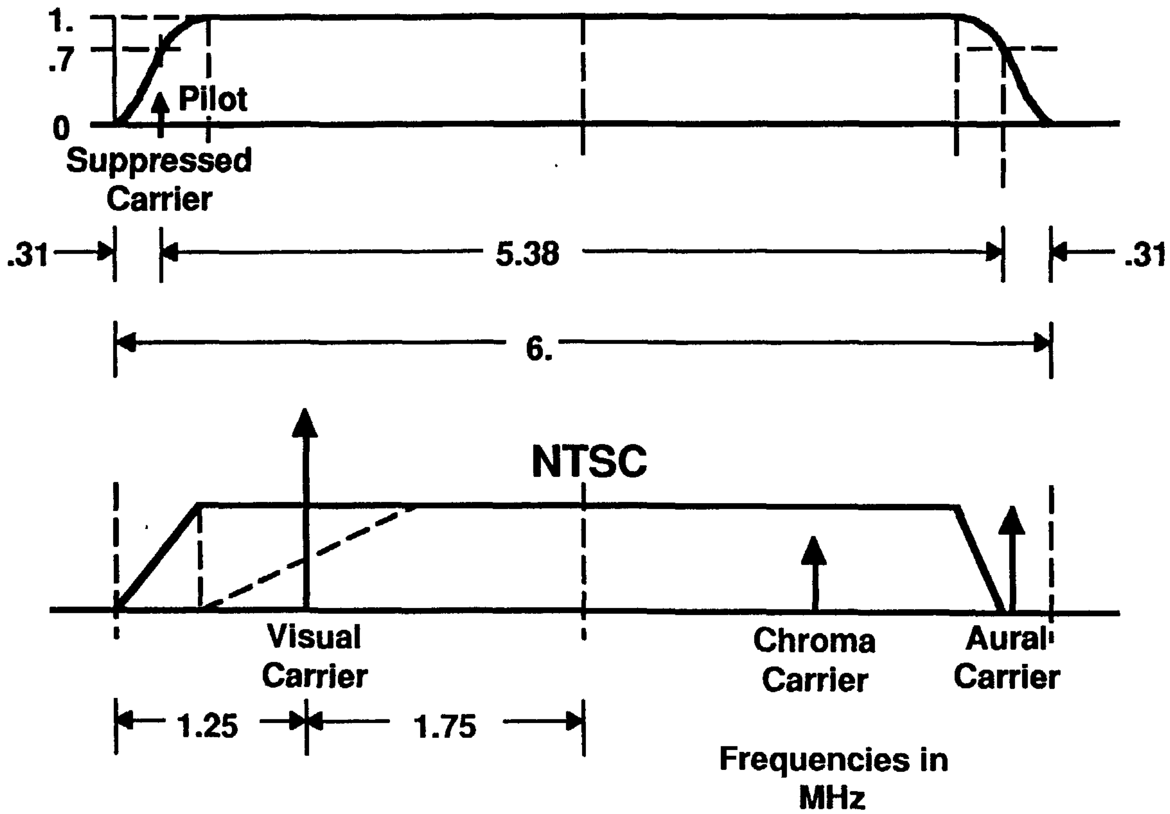


Figure 22

CUMULATIVE DISTRIBUTION FUNCTION OF 16-VSB PEAK-TO-AVERAGE POWER RATIO

Figure 23

16-VSB ERROR PROBABILITY

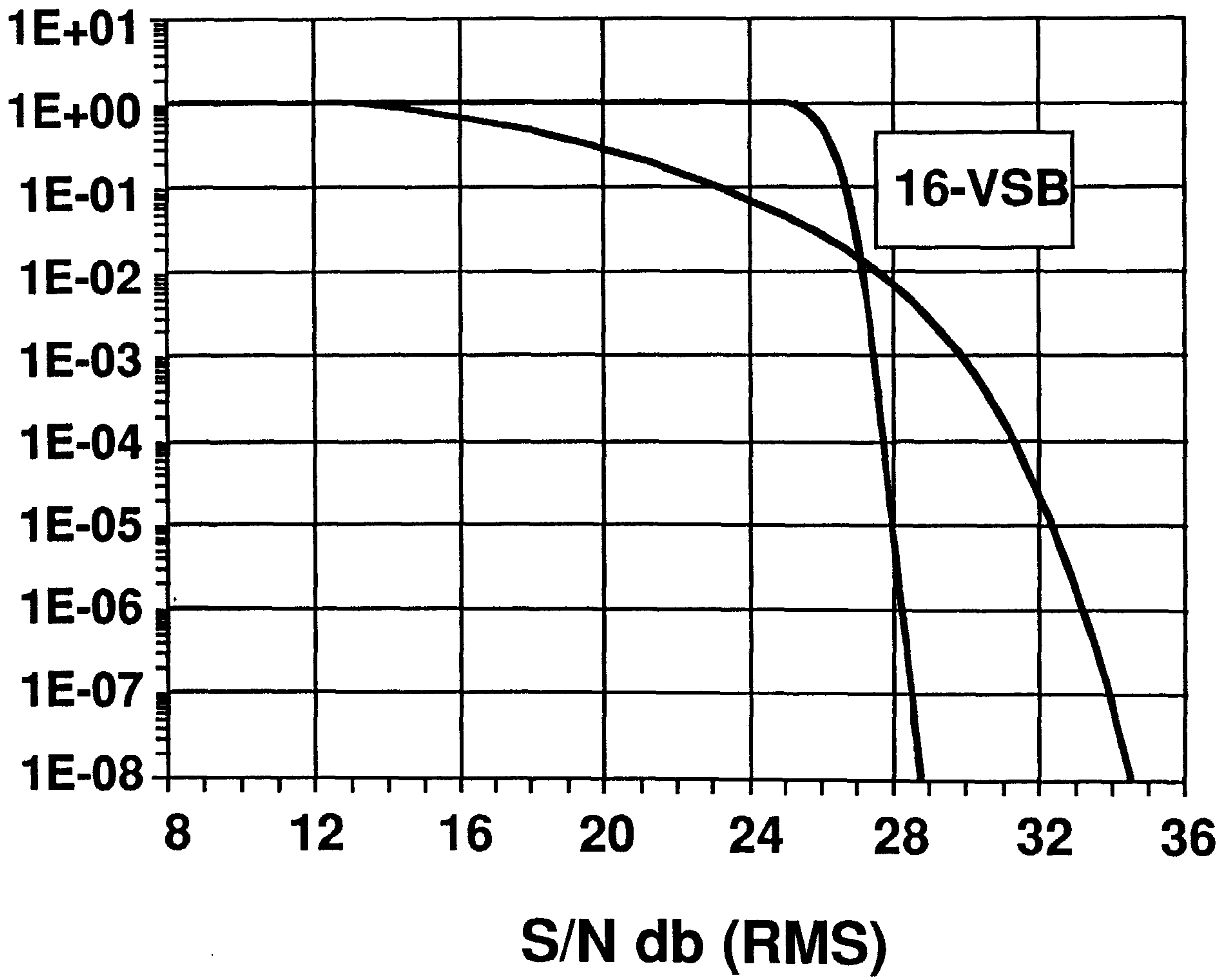


Figure 24

VSB DATA SEGMENT (Cable)

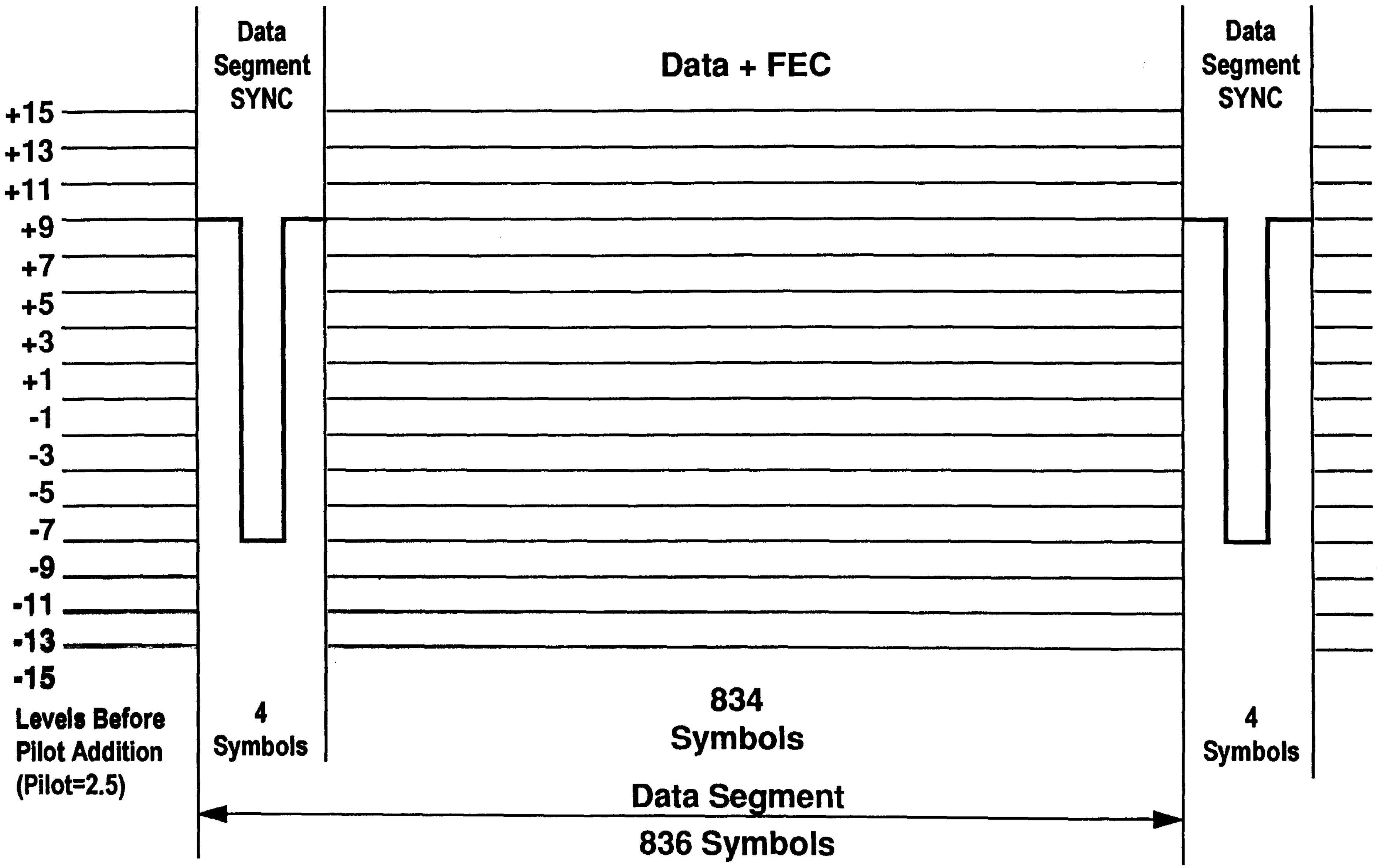


Figure 25
16-VSB TRANSMITTER